LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Lubrication of Power Transmission and Speed Reduction Mechanisms

THE tendency towards continued increase in the operating speeds of modern industrial plant machinery has given rise to problems of maintenance which were usually of little concern but a few years ago.

Take the matter of friction, for example.

When men and machinery used to dub along, the latter, at speeds which could not be tolerated in modern industry, there was little to worry about provided machines were properly designed, clearances adequate, and enough lubricant periodically applied to the relatively slow moving wearing elements to prevent actual metal-to-metal contact.

High temperatures were as yet but a rare problem in this matter of industrial machine lubrication, for frictional conditions were simply not of sufficient intensity to promote them, —unless, of course, external conditions were abnormal, as for example, in the steel mill, etc. So it was not as necessary to take into consideration the factor of "operating viscosity," *i. e.*, the viscosity of a lubricant at such actual temperatures of operation as might be a consequence of speed plus internal friction within the lubricant.

Increase in speed conditions in the operation of more modern industrial plant machinery, however, necessitates careful consideration of this factor today. Especially is this true in regard to speed reduction mechanisms, whether they may involve gears, chains, belt drives or frictional elements.

The essential parts of such systems which will require lubrication, are the bearings of sprocket, gear or pulley shafts, and all chain links and gear teeth, according to the type of drive involved.

It is safe to regard this matter of lubrication as the salient factor in the attainment of higher operating speeds, for without proper reductions in frictional resistance these will be practically impossible, with any degree of safety or assurance of continued, efficient operation.

Reduction Gears

Perhaps the most widely known mechanisms for power transmission and speed reduction purposes involve gears of varying size and type, according to the speeds developed and the relative directions of motion which may be necessary.

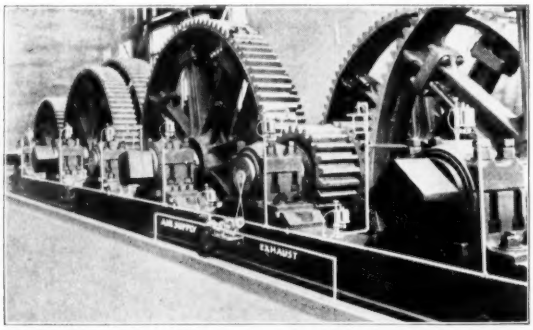
GEAR LUBRICATION

Essentially, gears will consist of circular discs, wheels or shafts, the surfaces of which are notched or cut out to form a series of very accurate teeth which are designed to mesh with other teeth of similar pitch or shape, which are cut on other gears, or perhaps on a straight surface to form what is known as a rack.

As a rule, gears will be so much larger, comparatively speaking, than other wearing parts on the average machine that very often the impression will be gained that their relatively massive construction warrants but little attention from a lubricating point of view.

As a result, the practice is all too prevalent

to ignore them or merely daub the tips of their teeth with dirty waste oil and forget them—though never forgetting to complain about their noisy operation.



Courtesy of S. F. Bowser & Co., Inc.

Fig. 1—An installation of Farrel Foundry and Machine Company gears, equipped for automatic lubrication of gear teeth and bearings. Note oil piping and lubricators in white outline, and the provision for application of air pressure.

Relation to Production

Gear lubrication involves more than the mere prevention of wear or elimination of noise. It ties directly back to production. In other words, noise is nerve-racking, and wear may some day require replacements; but back of all this is the development of inaccuracy, which, to the progressive, industrial engineer, is an unpardonable fault in a machine.

Then, as to the matter of power consumption; it is surprising how much power can be unnecessarily wasted as a result of neglect and a lack of appreciation of the fact that gears are in general quite as accurately designed as any other machine details.

Furthermore, faulty gear operation which may be the cause of shut-downs, stripped teeth, etc., may frequently involve considerably more serious difficulties than do worn cams, chain links or bearings.

Theory Involved

In the transmission of power by means of gearing we should theoretically be only involved with pure rolling motion between the surfaces of the gear teeth as they pass into and out from mesh.

On the other hand, it is practically an impossibility to attain this ideal, and regardless of the accuracy with which the teeth may have been cut, there will occur a certain amount of sliding motion.

Perhaps this is one reason why so many of us are prone to regard gear lubrication as of but little consequence, figuring that the greater proportion of the motion involved will be rolling. We must not forget, however, that sliding motion will impose considerably more wear on the gear teeth than will rolling motion. Furthermore, as wear continues to occur, more and more will rolling motion be supplanted by sliding motion.

Whatever the nature of the friction involved it will depend to a considerable extent upon the alignment of the gears, the accuracy of their cutting and the freedom of movement with which their teeth engage or mesh. Under ideal conditions, the teeth should roll so smoothly into each other and with such a constant relation in velocity between their respective surfaces that this friction will be reduced to a minimum. In this connection the lubricant, if it is properly prepared and carefully applied, will play an important part in the reduction of noise, the elimination of vibration or chattering between the teeth and the prevention of abnormal wear.

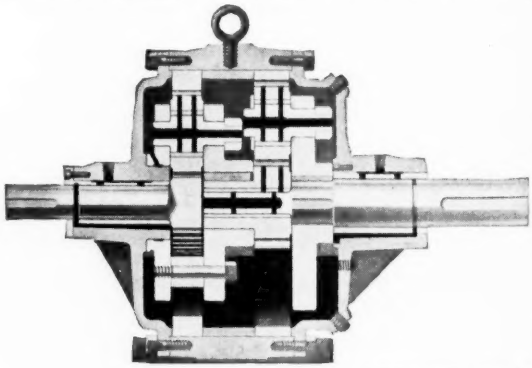
General Types.

For the purpose of identification and further discussion, it is deemed advisable to itemize circular gearing according to trade standards; in other words, we will be concerned with gears of the spur type; the spiral or helical variety; bevel or angular devices; the annular type and the worm drive.

Each will be distinctive according to the manner in which the teeth are cut, the general appearance or shape of the gear and the axial direction in which the motion is to be transmitted.

Spur Type Gears

Spur gears are those which comprise cylinders, discs or wheels with teeth cut thereon in parallel with the axis and each other. Their essential purpose is to transmit motion from one parallel shaft to another. The direction of rotation will, of course, depend on the number of such gears involved in the train. With an even number motion will be reversed;



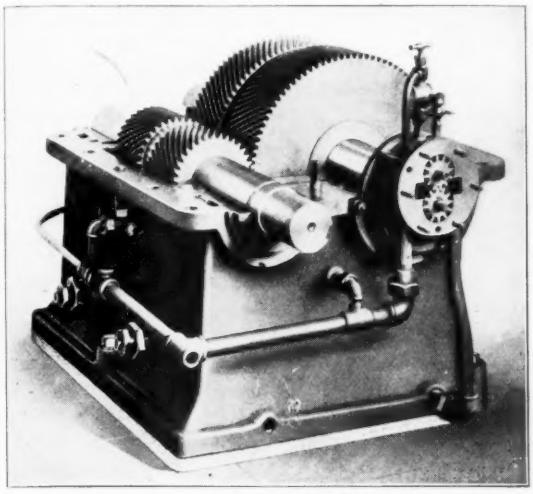
Courtesy of William Ganschow Co.

Fig. 2—Sectional view of a planetary type speed transformer showing oiling arrangement in heavy black outline.

in other words, the direction of rotation of the last member will be opposite to that of the first. An odd number of gears, or the use of intermediates as they may be called, will serve to

bring about the same direction of rotation in the driven gear as exists in the pinion or driver.

The use of intermediate gears for the purpose of bringing about certain directions of motion,



Courtesy of Westinghouse El. & Mfg. Co.

Fig. 3—Uncovered view of a herringbone type reduction gear set showing provision for oil distribution.

or the operation of intermediate shafts, will have no effect upon the relative speeds of the driving and driven gears.

Spur gears are very extensively used on a great variety of industrial machinery where medium tooth pressures and average speed conditions are involved. According to the type of service, they may be built encased or exposed.

As a rule this will depend upon the extent to which foreign or abrasive matter would be present, or the requirements as to safety. Gears should in general be guarded, but whether or not these guards are oil-tight is another matter.

Factors Affecting Lubrication

Oil-tight casings permit of bath lubrication and this in turn insures the utmost protection of the teeth, provided the oil is of a body or viscosity commensurate with the pressures involved.

On an average a lubricant in the neighborhood of 100 to 200 seconds Saybolt viscosity at 210°F., will be best for bath-lubricated gears.

Where gears are exposed, however, a heavier product will generally be necessary for the lubricating film must be capable of adhering tenaciously to the teeth, resisting temperature changes, and the effects of speed and centrifugal force which would tend to throw off the lubricating film.

Spiral, Helical or Herringbone Type

Spiral, helical and herringbone gears in turn will include all gears of a cylindrical nature which have their teeth cut on an angle or in helical form. Like spur gears, they are generally used for the connection of parallel shafts, although it is possible to design them in the form of bevel gears.

The lubricant on such gears performs an especially important function as a noise and vibration eliminator. In fact, the reduction of vibration is equally as essential as the maintenance of a lubricating film.

On gears of this type vibration or rattling, due to imperfect adjustment, uneven operation, or an insufficient film of lubricant, is claimed to promote pitting along the pitch line. This will be especially true if the gears are not properly aligned, or if cutting of the teeth has not been properly done.

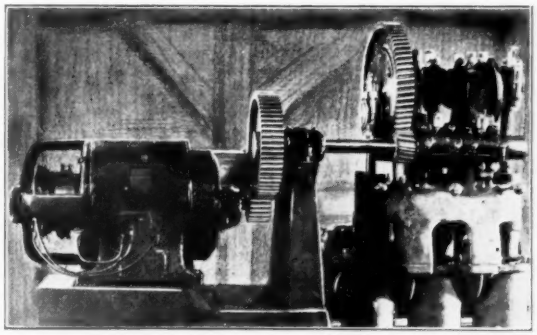
Lubrication

Gears of the herringbone type generally run in a bath of lubricant or are equipped for force feed lubrication as is the case with reduction-geared turbines. Here, as in certain other types of installations, it is frequently essential and desirable to use the same grade of lubricant on both gears and the adjacent bearings. For this purpose an oil of from 300 to 750 seconds Saybolt at 100°F. will usually be preferred, depending on the intensity of operation, class of service and size of gears.

On the other hand, where such gears are bath lubricated it may often be more satisfactory to use a heavier-bodied product, especially on larger installations. Here the viscosity range may vary from 100 to 200 seconds Saybolt at 210° F.

Bevel and Angular Gears

Where motion must be transmitted through gearing at an angle within the same plane, if at right angles the gears are called beveled; otherwise, they are termed angular gears. With gears of this type the teeth are cut on an angular surface such as would be represented by a truncated cone. The size and relative speeds of the



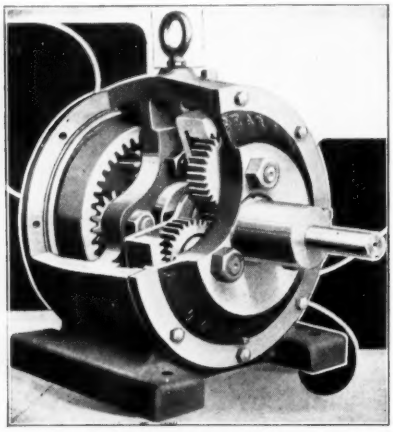
Courtesy of R. D. Nuttall Co.

Fig. 4—A set of spur and herringbone gears used as the drive for a vertical pump. Exposed gears require careful attention to lubrication.

gears is used to further identify them. That is, gears of the same size are known as mitre gears, whereas if the size is unequal they are termed angle reduction gears.

Lubrication Requirements

From a lubricating point of view, such gears, as a whole, will differ but little from spur gears, in fact, only in regard to the relative amount of sliding and rolling motion which will occur.



Courtesy of Foote Bros. Gear & Machine Co.

Fig. 5—Cut-away view of a spur gear speed reducer, showing relation of gears.

As a rule there will be more of the former than with other types of gears, due to the frequently greater difficulty involved in the accurate cutting of teeth and alignment of the respective shafts.

To meet these possible difficulties it is therefore oftentimes preferable to use a somewhat heavier lubricant, which will furnish a sufficient film to not only take up any shocks involved, but also to resist the wiping effects of sliding motion.

Annular Gears

A circular gear with teeth cut over the internal instead of the external surface is known as an annular gear. The companion pinion, however, must, of course, be a standard type of spur gear, with external teeth cut to the proper pitch to mesh with those on the annular.

Such gears are adaptable to relatively large speed reductions. Typical examples of their usage are: the main driving elements of certain tractors, and the reduction mechanisms on some types of textile machines.

Lubrication of annular gears involves much the same conditions as spur gears. In fact, where they operate exposed, practically the same grades of straight mineral semi-fluid lubricants as would be required on exposed spur gears will be applicable.

The effect of centrifugal force on an annular gear, however, is naturally the reverse of that on a gear with externally cut teeth. Hence, there will not be the same tendency for the lubricant to throw off, except as it is taken up by the spur teeth of the driving pinion. Certain installations on the other hand will be designed for bath lubrication. Here, of course, a lighter, more fluid oil, commensurate with the pressures and size of the teeth, can be used to good advantage.

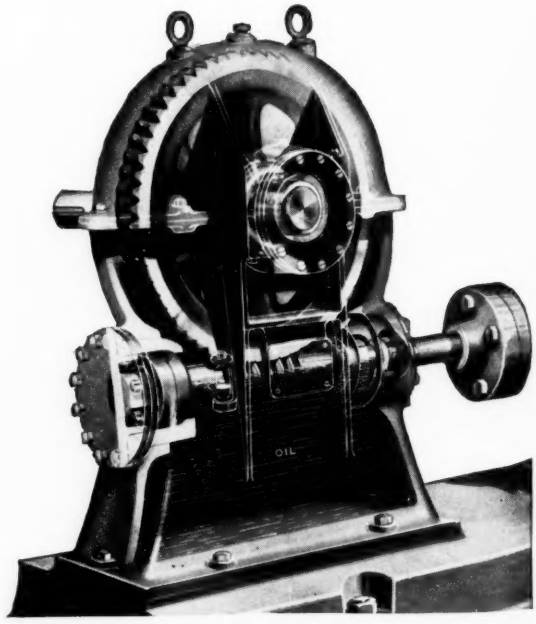
Worm Reduction Gears

Worm gears are advantageous where motion is to be transmitted between two non-intersecting shafts, located at right angles to each other and not in the same plane. A worm gear is a cylinder, on the surface of which several continuous helical teeth are usually cut, and which extend round and round over more or less the entire length. The worm is usually the driving element. Its companion mechanism is a standard type of gear. The entire mechanism is generally known as a worm reduction gear.

Worm Gear Lubrication

Due to the manner of housing, worm reduction gears can generally be bath or splash lubricated. Operating and constructional conditions, however, will require a relatively wide variation in the viscosity of the lubricant.

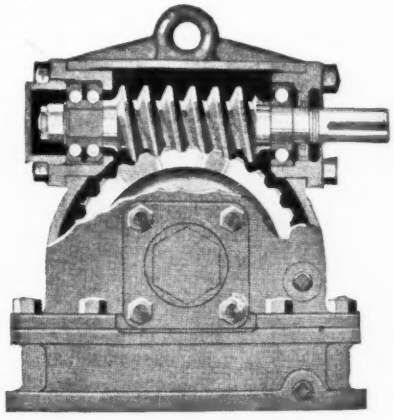
In certain instances, for example, a gear lubricant of approximately the viscosity of a straight mineral cylinder oil will be required. In others a machine oil, of from 300 to 750 seconds Saybolt viscosity at 100°F. will suffice. Essentially the problems are to maintain the



Courtesy of The Cleveland Worm & Gear Co.

Fig. 6—Phantom view of a motor-driven worm reduction gear showing oil bath and reservoir.

requisite film of lubricant on the gear and worm teeth; to reduce the starting and operating torque as far as possible; and to lubricate the shaft bearings with a minimum of frictional resistance



Courtesy of Albaugh-Dover Mfg. Co.

Fig. 7—Cut-away view of a worm gear speed reducer with worm located above the gear. Careful choice of the gear lubricant is necessary to insure effective lubrication of the worm teeth, wherever the gear must carry the oil thereto.

Use of Ball and Roller Bearings

Ball and roller bearings are extensively used in such installations, especially for the worm shaft, and for the purpose of taking up end thrust. Anti-friction bearings of this nature should be served with as low a viscosity lubricant as possible, for essentially the function of this latter is to protect the highly polished surfaces rather than to lubricate. So a compromise will often be necessary, especially when the one lubricant must be used throughout the gear set.

Oil Level Important

Where worm gears are bath lubricated the level of the oil is of decided importance. We must remember that the development of "drag" or excessive internal friction may become a decided factor in the matter of power consumption. So as a rule the oil should be carried at such a height as to insure suitable dipping of the teeth of the lower element; submergence of too much of either the gear or worm is not advisable.

Provision will usually be made for distribution of the lubricant via the teeth of the gear to the respective shaft and thrust bearings, or else these will be provided for external or independent lubrication.

Where the worm is located below the wheel or gear, the oil level should usually be carried at the center line of the worm shaft. Where the worm is above the gear, however, the problem may be more difficult, for the gear teeth will carry less lubricant to the worm than this latter would to the gear teeth. So a heavier, more adhesive lubricant may often be necessary, or the level of the lubricant may have to be raised to a certain extent.

Selection of Gear Lubricants

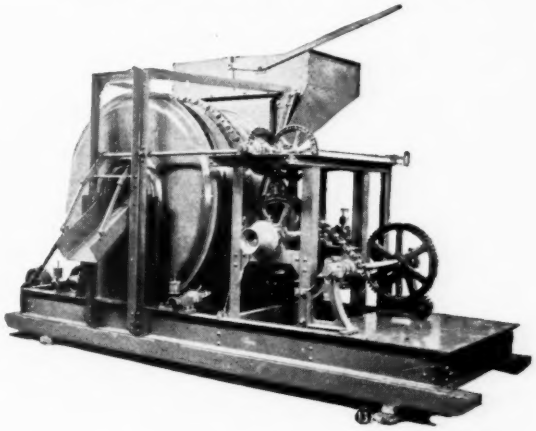
There are certain definite properties which gear lubricants should in general possess if they are to function effectively, viz.:

1. Adequate lubricating ability or "oiliness" to insure the maximum reduction of both solid and fluid friction.
2. Viscosity commensurate with the method of lubrication and the amount of heat that may be encountered.
3. Sufficient adhesiveness so that in event of use under exposed or semi-enclosed conditions a requisite film will remain on the teeth to resist the effects of centrifugal force.
4. As little tendency as possible to congeal, harden, crack or become brittle when used under lower temperature conditions; or, to carbonize and chip if exposed to abnormally high temperatures.

To meet these requirements, considerable attention has been devoted to the preparation of gear compounds by the oil industry.

In general they will vary all the way from fluid mineral oils to the numerous preparations of the nature of grease, or other artificially thickened products containing talc, rosin, etc. The ultimate object is, in practically every case, to meet viscosity requirements.

Non-lubricating fillers will increase the plasticity but they oftentimes reduce the ultimate lubricating ability of the product to a marked

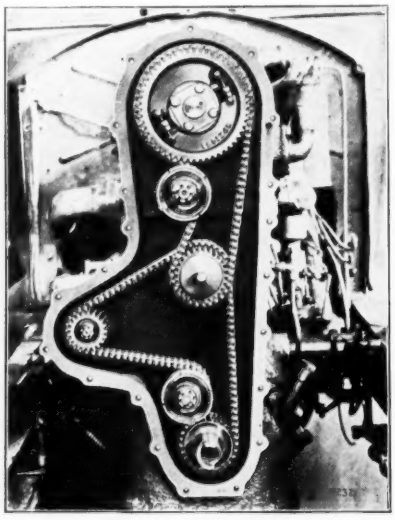


Courtesy of Chain Belt Co.

Fig. 8—View of a concrete mixer with a drive involving spur and bevel gears, and roller type chains.

extent. Therefore, they should be guarded against. In addition, lubricants with such content will lack to an appreciable degree the adhesive characteristics which may so often be of vital necessity. As a result, when they are

used under exposed conditions, on high speed gears, subjected, perhaps, to the detrimental effect of water, acids or alkalies, the gear teeth may suffer materially due to the inability of these lubricants to resist the effect of centrifugal force, the washing action of water or the corrosive effects of certain chemicals, etc. In consequence, a straight mineral product should be used wherever possible.



Courtesy of Link-Belt Co.

Fig. 9—Showing the adaptability of the silent chain drive to the internal combustion engine front end drive.

Grease Lubrication

In connection with this matter of selection of gear lubricants a word as to greases will be pertinent.

Broadly speaking, greases should only be used as gear lubricants under special conditions, due to their lack of adhesion and their tendency to squeeze out from between the teeth, leaving an imperfect lubricating film. It must be remembered that from a lubricating point of view greases are only as good as the mineral oil which they contain. Their soap content is merely a carrier, to give the requisite body to the resultant product. Soap does not lubricate to any material extent, though it may serve as a cushion provided tooth pressures are not too high.

Greases are applicable as gear lubricants wherever their characteristics will meet the pressure and temperature conditions prevalent.

In certain cases they are suited to automotive service where relatively light-bodied products may be required and where an oil-tight case is available. Here the gears run in a bath of the lubricant which will generally be of a semi-fluid nature.

Greases are also advantageous on smaller gears, such as are so frequently employed on textile machinery, printing presses, baking machinery, etc. Such gears frequently cannot be bath lubricated due to the manner in which they are housed or guarded.

Chain Drives

Chain drives, as applied to power transmission and speed reduction, will, as a rule, involve the roller type chain or the so-called silent chain. In general, chain drives are employed for transmission or reduction of speed over distances which would render gearing an expensive and intricate matter, and yet which would be too short for the effective usage of belting or rope drives.

Theoretically it would be perfectly feasible to build a train of gears over any distance. Practically, however, this would be an economic impossibility due to the expense and amount of material which would be involved. The adaptability of the chain drive under conditions of moderate distance between the driving and driven elements, is noteworthy.

TYPES OF CHAINS

Roller Chains

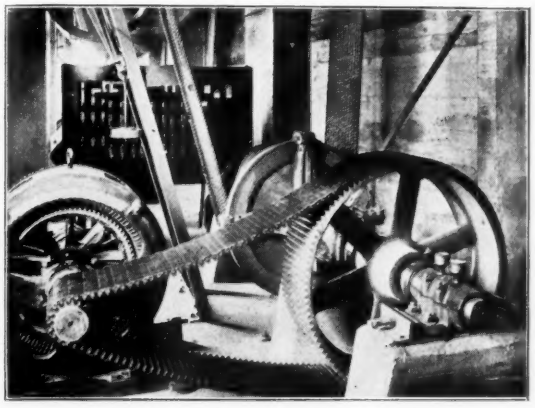
Roller type chains are used where a relatively inexpensive, heavy duty, durable chain is required, and where moderate noise is not a serious objection. In reality they extend the application of the efficiencies of a chain drive system to classes of work where normally the usual economies of modern industrial power transmission are lost sight of. They are furthermore applicable to a grade of service wherein a silent chain would be an expensive refinement, and yet where a cheaper rough chain of the pintle type could not be used.

On account of the high speeds that may be required, roller chain bearing surfaces are machined to a smooth finish in order to enable effective lubrication, and insure against abnormal wear. Sprocket teeth are also constructed in the same manner. The extreme service under which certain tractor and automobile truck chains operate is an excellent example of what an average roller chain must be capable of enduring. As well, it is an ideal example of how the subject of chain lubrication enters into the question of chain operation.

Silent Chain Drives

Silent chains include all such driving mechanisms as are built up of parallel series of links fastened to each other and to the adjoining links by pins and bushings, or seat and rocker pins.

The effect of constructions of this nature is to give exceptional articulating or bending ability to the entire chain, with very little wear and noise, provided lubrication has been properly carried out.



Courtesy of Morse Chain Co.

Fig. 10—A contrast photo showing the chain belt and rope drive adjacent to each other—each decidedly effective where judiciously applied. Note grease lubricated bearings.

Due to the usual oil economy which is obtainable on certain chains of this nature, and the possibility of reduced lubrication, little or none of the lubricant will normally be thrown off by centrifugal force, even under the higher speeds which are often prevalent. Therefore, cleanliness of operation is usually an adjunct, especially on overhead installations where the chains and sprockets are often exposed.

FACTORS GOVERNING CHAIN LUBRICATION

To insure proper and efficient lubrication of driving chains, it is decidedly essential that operating conditions be studied. In fact, only by combining a knowledge of such factors as speed, load, clearances and extent of bending or articulation can proper lubrication be determined upon. For example, a fluid product that would be adaptable to silent chains might often be altogether too light to suit the clearances prevalent in a roller chain.

Speed Conditions

Speed is important, since it involves the frequency of shock due to engagement of the chain links with the gear or sprocket teeth. In other words, the greater the speed the more frequent will be the shock on each link.

Whether or not shocks of this nature will be detrimental to lubrication will depend upon the load and constancy of operation. It is natural to expect that the rapid repetition of such shocks upon the bearing points of the chain will tend to force or squeeze the lubricating film out from between the rollers and bushings, or rocker bearing surfaces.

It is not generally possible to compensate for this condition by increasing the viscosity of the lubricant to any great extent, as is often done on heavily loaded bearings, due to the fact that the penetrative ability of the lubricant would thereby be markedly decreased.

Bending or Articulation

The extent of bending or articulation of a driving chain imposes wear not only on the link pin bearings, but as well at the points of contact between the chain and the gear or sprocket. In fact, this is the chief cause of external wear, both of the chain and sprocket notwithstanding that correct chain design endeavors to eliminate as far as possible this tendency towards friction and external wear, confining necessary rubbing or rolling to the joints.

Pins, bushings, rollers, etc., are therefore customarily built with adequate bearing surface to take up the usual strains. Still, a certain amount of external wear will be present at any event, and for this reason an adaptable chain lubricant should be capable of effectively serving both internal and external wearing points.

Clearance a Factor

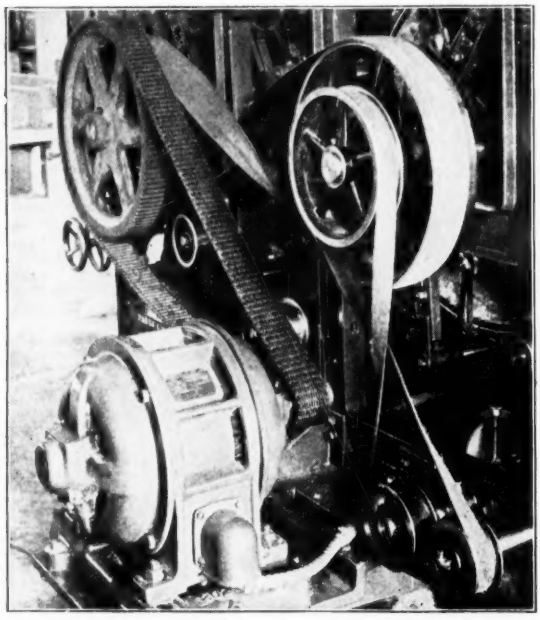
Depending upon the existing clearances, the lubricant must have a certain amount of fluidity in order to be able to penetrate thoroughly throughout the entire link whether pins and bushings, rollers or rocker joints are involved. On the other hand, to adequately prevent external wear of teeth and chain a relatively, heavy adhesive lubricant should be used, which will adequately resist the effects of centrifugal force and stick to the wearing surfaces. Such a lubricant, being regarded as semi-solid, is naturally too viscous to serve the internal bearings. Hence a compromise must be effected whereby sufficient viscosity reduction is obtained to meet one purpose, yet with the retention of adhesion as much as possible. Certain steam cylinder oils, or reduced petroleum residuums have been proven to be the best bases for such a lubricant. Where necessary they can be blended to the desired viscosity with lighter, straight mineral products.

Foreign Matter a Detriment

When chains must be operated in the presence of dust, dirt, chemical fumes or water, the duty imposed upon the lubricant will, of course, become all the greater. In such cases not only must it serve as a lubricant, but as well, as a protective agent for the bearing surfaces.

Grit, dust, acids and moisture will tend to promote wear and corrosion to a marked extent.

Grit and dust in particular being of an extremely penetrative nature will always tend to work into clearance spaces and immediately increase the wear. As a result, unless the lubricant is of the proper viscosity and base, it will often become incorporated with such foreign matter and develop into an abrasive paste similar to a valve grinding compound.



Courtesy of The Whitney Mfg. Co.

Fig. 11—The drive of a wool finishing machine involving both the silent chain and the belt.

SELECTION OF LUBRICANTS

The essential requirement of a chain lubricant is that it must adequately penetrate to the rollers, rockers or sliding surfaces of the links. It does no good to apply a lubricant to the surface of a chain if it has not the penetrative ability to reach all wearing parts by virtue of its viscosity and the clearance between the wearing surfaces.

Roller Chains

In regard to roller chains, oftentimes, little attention is given to them due to their seemingly rough construction, and waste oils may be carelessly slopped on at intermittent intervals. Waste oils will lubricate, but due to the fact that they may often contain quite an appreciable amount of sludge and abrasive matter their application is not recommended. It is far better to use a lubricant which has been especially refined to meet the conditions of construction and operation, as mentioned above.

In application it is customary to brush the lubricant uniformly over the wearing surfaces while they are operating slowly. It will be found advisable to heat heavier products in order to facilitate the spreading of a thin, even coating.

Silent Chain Conditions

Silent chains may be operated exposed, or in an oil-tight casing. The speed of operation is oftentimes regarded as a guide as to whether a casing should be used. However, in service where dust, grit or other foreign matter is present a casing is always advisable whatever the speed.

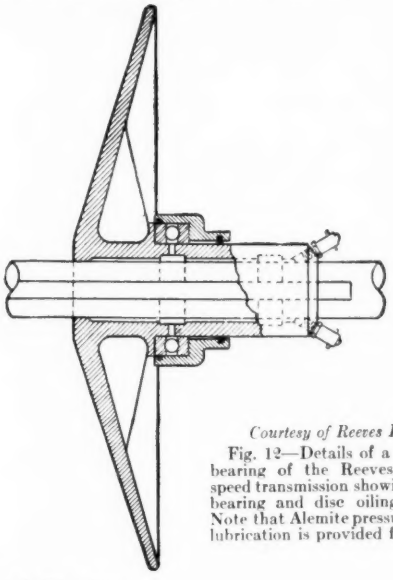
Naturally a chain which operates in a dust-proof, oil-tight casing which is equipped with some form of automatic lubricator, will require the least attention, and operate most efficiently.

An effective type of casing chain-lubricator makes use of the principles of splash lubrication by means of a disc or collar attached to one side of the main shaft. As the wheel rotates the disc dips into the oil in the base and throws it to the top of the casing which is built in the shape of a wedge. As a result there is a continuous dripping of oil upon the chain. In casings of this type the oil level is below the chain, the disc dipping in it to a certain extent.

Other types of casings depend upon bath lubrication, in which event the oil level should be somewhat above the lowest part of the chain.

Pressure Lubrication a Factor

Casings which are used on high speed chains are often equipped with an oil pump. Pressure lubrication is thereby attained, the oil being sprayed continually upon the chain.



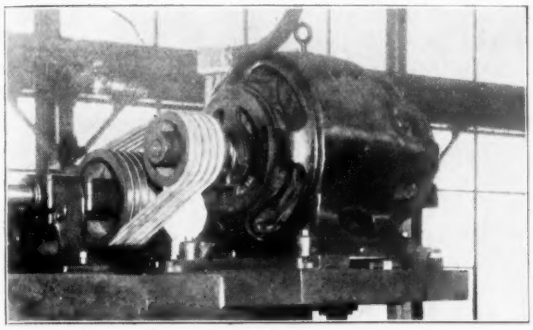
Courtesy of Reeves Pulley Co.

Fig. 12—Details of a disc and bearing of the Reeves variable speed transmission showing thrust bearing and disc oiling system. Note that Alemite pressure grease lubrication is provided for.

Exposed Chains

When silent chains are operated exposed, the lubricant must be applied either by brushing it uniformly over the driving surface, or by removal and immersion of the entire chain.

Certain manufacturers of chains of this nature treat them with the lubricant before they leave the factory, in order to give them a good start in life. Usually a soaking bath is used, the chains being immersed for a sufficient length of time to allow penetration to all interior parts. Subsequent soaking of the chain in the lubricant at periodic intervals is advisable wherever possible.



Courtesy of Allis-Chalmers Mfg. Co.

Fig. 13—An interesting development in power transmission work is the "Texrope" drive. A number of individual fabric belts are involved, cut to an angle to run in companion grooves on their respective pulleys. Pulley bearings are of course the essential parts requiring lubrication.

When it is impossible to remove a silent chain for such treatment, the bearing or inner driving surface should be brushed with a light uniform coating of lubricant about once a week, or more frequently if necessary. If this is done during slow operation, satisfactory penetration will occur to all the joints through the combined effects of bending, capillary action and centrifugal force.

Due to the fact that clearances in silent chains are usually very small, it is generally advisable to use a relatively fluid straight mineral lubricant. When chains are encased, if they are to be bath lubricated, an engine oil having a viscosity of about 500 seconds Saybolt at 100°F. will be suitable. Where exposed, or encased but not submerged in oil, a heavier lubricant such as a mineral cylinder oil or light gear lubricant should be used.

Considerable difference of opinion often arises as to the use of greases or other semi-solid products. In many cases these would serve the purpose admirably, especially on such chains as have sufficient clearance to enable proper penetration.

Importance of Cleanliness

In conclusion it is well to remember that chains and casings will often require cleaning, especially if operating conditions are not of the best, or entry of dust or dirt occurs. In such cases a kerosene or gasoline wash will be found satisfactory. Chains should be removed if possible and immersed in this wash. Cases should be drained and rinsed out to insure the removal of all sediment that may have collected.

Belt and Rope Drives

BEARING LUBRICATION

Where power transmission requires the use of belt or rope drives, that is, where distances between driving and driven mediums are comparatively high, the problem of lubrication will be confined solely to the bearings of the pulleys, sheaves or such shafting as may impart or receive motion.

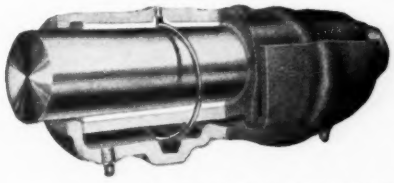
Pulley and sheave bearings may be grease or oil-lubricated, all according to the nature of their design and construction.

RING AND CHAIN OILERS

Lubrication of bearings by ring or chain oilers involves continual delivery of oil to the wearing surfaces by means of a ring or chain suspended from the shaft, and free to rotate therewith, the lower part dipping in a bath of oil which is carried in a suitable reservoir.

In order to insure effective lubrication by such mediums the reservoir must be of adequate capacity to give the oil ample opportunity to rest, thereby making possible not only the settling out of sediment and other foreign matter, but also cooling to the requisite degree. As a rule the only way in which the oil in such a system is kept at the proper temperature is by radiation of heat from the exterior surfaces of the reservoir or lower part of the bearing.

Should the latter be of apparently insufficient capacity it is possible to overcome this by fitting an auxiliary reservoir below the one in question. One way in which this can be done is to tap a short length of pipe into the lower part of the bearing, plugging the bottom end with a cap. Such a device has an added advantage in that it also acts as a dirt collector.

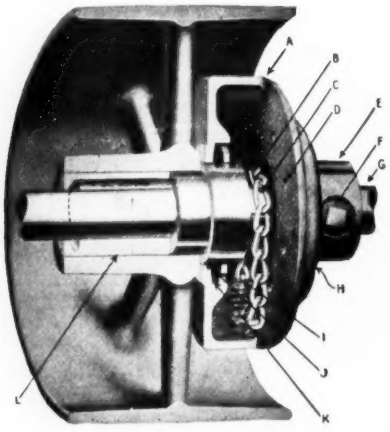


Courtesy of Dodge Sales & Engineering Co.

Fig. 14—Details of a ring-oiled bearing showing relation of the ring to the journal, and the constructional features of the bearing and oil reservoir.

Oil which is carried to the top of a ring or chain oiled bearing must of course be taken care

of and returned to the reservoir as rapidly as it is delivered by the ring. If this is not possible, oil will tend to accumulate in the upper part of the housing to ultimately be forced out from the ends of the bearings.



Courtesy of Standard Pressed Steel Co.

Fig. 15—View of a chain oiled self lubricated loose pulley. Note A—the oil chamber; B—the oiling chain; C—the bushing; D—the holes to permit oil to enter the oil chamber on filling; E—the hub; F—the set screw to hold oil chamber to shaft; G—the shaft; H—the oil-filling hole; I—the oil level; J—the running fit between oil chamber and bushing; K—an oil seal groove; and L—the pulley bushing.

The same condition may arise if the oil is carried too high in the well, or if the ring rotates at too high a speed. This will cause a splashing and churning of the oil.

Selection of the Oil

Under normal temperature conditions such equipment will require the use of a high grade straight mineral oil of approximately 150 to 200 seconds Saybolt at 100°F.

In determining the viscosity of such an oil, the bearing construction should be investigated; oftentimes if oil returns are too small they may become clogged, causing heavier oils to overflow.

Inasmuch as power transmission and speed reducing drives may frequently have to function under abnormally low temperatures, an oil with a low cold test should be chosen wherever possible. If this latter approximates zero degrees F., the oil will generally function satisfactorily.

On the other hand, higher temperatures will oftentimes require additional viscosity to resist the thinning down action of heat. Under such conditions, an oil of from 300 to 400 seconds viscosity or even higher may be advisable.

COLLAR OILERS

In a study of power transmission and speed reduction mechanisms, it will also be of decided interest to take up the collar type of oiler as adapted to pulley and line shaft bearing lubrication.

The principle of this device is much the same as that of the ring oiler, *i.e.*, it involves the circulation of oil from a suitable reservoir in the base of the bearing. This is brought about by means of a collar of considerably larger diameter than the shaft, which is fastened to the latter at approximately the center of the bearing.

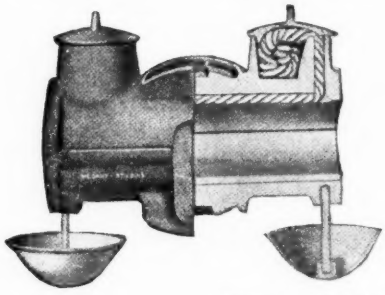
Lubrication, however, may be regarded as of more essentially the flood variety. Furthermore, it will, as a rule, be more positive than in the average ring oiler, by virtue of the fact that as soon as the shaft begins to rotate the collar being fast thereto will likewise be set in motion to immediately carry oil to the top of the bearing. As a result, the requisite film of lubricant will be formed more rapidly on starting and maintained more effectively, especially under slower speed conditions.

An added advantage which is claimed for the collar type bearing oiler is that there is relatively no possibility of cessation of lubrication as long as the oil level in the bearing reservoir is maintained at a high enough level to insure adequate dipping of the collar. Rings on the other hand, may tend to stick, or fail to revolve with the shaft, especially if the oil used becomes abnormally sluggish by reason of low temperature, or the entry of an excess of contaminating foreign matter.

BALL AND ROLLER BEARINGS

Anti-friction bearings of the ball and roller type have likewise been proven to be adaptable to such service, especially where certain requirements, such as space occupied, reduction in the amount of attention from a lubricating point of view, and positiveness of action must be observed.

Ball bearings can be lubricated either with oil or light grease according to the design of the bearing housings.

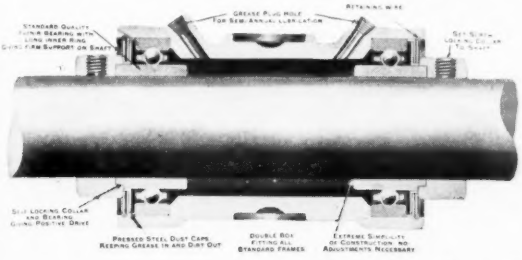


Courtesy of The Medart Company.

Fig. 16—A type of wick oiling hanger bearing. The wick is in direct contact with the shaft. Note drip cups to catch leaked oil at ends of bearings.

Roller bearings can be similarly lubricated, though the type and construction of the rollers must be considered in addition.

Whatever their type or lubricating requirements, ball and roller bearings occupy a minimum of space, and require re-lubrication, inspection and cleaning at very infrequent intervals. The customary housing design affords ideal protection against the entry of contaminating foreign matter, and the oil or grease consumption is normally very low.



Courtesy of The Fafnir Bearing Co.

Fig. 17—A double ball bearing hanger box showing constructional features in detail.

Principles Involved

From a constructional point of view, antifriction bearings involve rolling contact as compared with plain or sleeve type bearings wherein sliding contact occurs.

In ball bearings, this rolling contact is that of a theoretical point over a given surface.

Roller bearings, however, involve theoretical line contact between the journal or shaft element and the outer raceway.

As their names imply, such devices comprise a set of perfectly spherical balls or an arrangement of solid or flexible rollers. The latter will be cylindrical in shape, the distance between the inner and outer raceways being uniform throughout the length of the roller. Solid rollers, on the other hand, may be either cylindrical or tapered according to the type and design in question.

Whatever the nature of the rolling elements, however, such bearings in general must be carried or housed in much the same manner, *i.e.*, in suitable containers comprising raceways and cages. The inner race fits on the shaft, the outer being held by the pillow block or shaft hanger. Between them are located the balls or rollers. These are kept in their proper positions with respect to each other and to the races, by the separator, cage, or retainer. Rotation of the shaft sets up a rotary motion between the rolling elements and the respective inner and outer surfaces of the raceways.

Function of the Lubricant

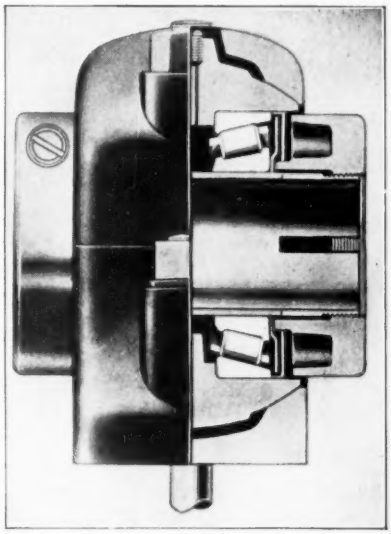
The purpose of lubrication is to facilitate as easy rolling as possible. To enable this, however, all the surfaces (which are of a highly polished nature) must be in as perfect condition as practicable. As a result the lubricant must serve the dual purpose of both lubricating, and protecting these surfaces against rusting, corrosion, pitting or abnormal wear.

Minimum clearance, of course, is an aid to proper functioning of such bearings, for the occurrence of any play between the component parts would tend to set up a certain amount of pounding which would be detrimental to effective operation. In other words, all motion must approximate perfect rolling.

In general, as light a lubricant should be used as can be successfully retained in such a bearing commensurate, of course, with the temperatures and pressures involved.

Ball bearings are claimed to involve less friction to a certain extent due to the fact that there is little or no end thrust involved. As a result, the lubricant in such bearings serves more nearly the purpose of acting as a metal-protecting medium. In view of this fact, and to reduce the possibility of the development of abnormal internal friction within the lubricant, it is generally advisable to pay careful attention to the oil level.

Certain authorities contend that submergence of approximately one-half to three-quarters of the lowest ball will be sufficient. In this connection it is important to remember that contrary to the principles of plain bearing lubrication, the oil in a ball or roller bearing plays no part as a coolant. Therefore, volume is a detriment rather than an advantage.



Courtesy of The Timken Roller Bearing Co.

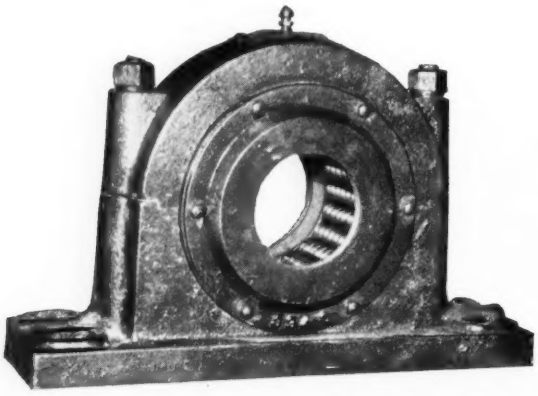
Fig. 18—Constructional details of a roller bearing type of pillow block.

Factors in Roller Bearing Lubrication

Lubrication of roller bearings by means of oil is subject to much the same conditions as stated in connection with ball bearings.

Where end thrust may develop to an appre-

ciable extent, however, due to difficulty in keeping the rollers in alignment, or where pressures or temperatures may be high it is the opinion of certain authorities that it will be conducive to better lubrication if somewhat heavier oils are used.



Courtesy of Hyatt Roller Bearing Co.

Fig. 19—A flexible roller bearing type of pillow block showing relative position of rollers.

Under such conditions the use of straight mineral lubricating oils of as high as 750 seconds Saybolt viscosity at 100°F. are advocated. Even mineral cylinder oils of a high degree of purity may be necessary under conditions of extremely high duty, pressure or temperature.

Conditions Requiring Grease

Where oil leakage may occur, however, or under conditions of dust, dirt or dampness, it may be advisable to resort to grease as the lubricant.

Greases furnish better seals against the entry of dust, dirt and moisture, thereby serving to protect the polished surfaces of the bearing elements in a very satisfactory manner. Grease also can be very much more effectively retained in a non-oil-tight housing. On the other hand, dirt or grit that finds its way into a grease lubricated bearing has no means of settling out, and may be held in suspension to ultimately cause scoring of bearings and shafting.

Greases which are comparatively fluid in consistency will meet average operating conditions where the lubricant must readily cover the entire surfaces of the balls or rollers and not tend to channel in the housings or raceways, as might occur with more viscous products of this nature which would have less of a penetrative ability.

On the other hand, under conditions of high temperature it might be necessary to resort to greases of greater body to withstand the thinning-out effects of heat, and prevent the consequent entry of dust or dirt.

Relative to the amount of grease to be used in a ball or roller bearing it is interesting to note that in the case of ball bearings the S.K.F. Industries, Inc., recommend that the housing be from one-quarter to one-half full. They further state that—

"A frequent cause of difficulty in the use of grease by those inexperienced with ball bearings, is forcing an excessive amount of lubricant into the housing by means of a compression cup or other device. This leads to heating and often results in melting and breaking down of the grease, so that its lubricating value is destroyed. As a result further heating takes place and the operator attempts to remedy this by the addition of more grease, thus aggravating still further the cause of the trouble. In such cases the oily or lubricating constituent will leak out from the housing, leaving the bearing entirely caked with the hard filler having no lubricating value whatever."

Greases for ball and roller bearing lubrication should be as free from acid forming tendencies as possible in order to insure adequate protection of the highly polished metallic surfaces. In effect this involves perfect neutrality, and of course the absence of non-lubricating fillers.

The presence of any material that might give rise to oxidation and the development of free acidity, or to decomposition or settling is also prohibited. Properly compounded products will meet these requirements satisfactorily under normal conditions of operation, and there should be practically no tendency for them to cause corrosion or pitting of balls, rollers or raceways.

CONCLUSION

It has only been possible, of course, to touch upon the high spots in this discussion of lubrication of power transmission and speed reducing mechanisms. As a result, detailed mention of certain methods of lubrication as for example, the pressure lubricator as applied to gearing, or the wick oiler for bearing service, has had to be confined to the illustrations alone. No partiality has been intended. It is hoped, however, that these latter have been so carefully chosen, and so judiciously captioned that they will be self-explanatory, and will tie up with the text so effectively as to give a comprehensive aspect of the problem as a whole, and an insight into the means of solution.

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